THERMODYNAMICS

Substance	Standard Heat of Formation, ΔH_f^o, in kJ mol^{-1}	Absolute Entropy, S^o, in J mol^{-1} K^{-1}
$C(s)$		5.69
$CO_2(g)$	–393.5	213.6
$H_2(g)$		130.6
$H_2O(l)$	–285.85	69.91
$O_2(g)$		205.0
$C_3H_7COOH(l)$	?	226.3

1. When 2.50 grams of butyric acid, $C_3H_7COOH(l)$, is completely combusted at 25°C and 1.00 atmosphere, $CO_2(g)$ and $H_2O(l)$ are formed with the evolution of 60.0 kJ.

(a) Calculate the molar heat (enthalpy) of combustion for butyric acid.
(b) Write a balanced thermochemical equation for the molar heat (enthalpy) of combustion for butyric acid.
(c) Calculate the standard free energy of combustion, ΔG^o_f, for butyric acid at 25°C.
(d) Calculate the equilibrium constant for the combustion of butyric acid.
(e) If 5.00 g of butyric acid is combusted in a bomb calorimeter, what will be heat capacity of the bomb if the temperature of the bomb goes from 25.0°C to 30.0°C?
(f) If 5.00 g of butyric acid is combusted in the part (e) bomb calorimeter and surrounding the bomb is 1.912 kg of water at 25°C, what will be the final temperature of the system? The specific heat of water is 4.184 J/g°C.
(g) From the above data, calculate the standard heat (enthalpy) of formation, ΔH_f^o, for butyric acid.
(h) Write a balanced thermochemical equation for the molar heat (enthalpy) of formation of butyric acid.
(i) Calculate the standard entropy change, ΔS_f^o, for the formation of butyric acid at 25°C.
(j) Calculate the standard free energy of formation, ΔG^o_f, for butyric acid at 25°C.
(k) Would the molar heat (enthalpy) of formation for $H_2O(g)$ be (more, less, or the same) when compared to the molar heat of formation for $H_2O(l)$? Explain.
(l) Calculate the volume of air at 25°C and 750. mm-Hg that is needed to combust 20.0 grams of butyric acid. Air is 20.0 percent by volume oxygen.
(m) Using the table below, calculate the bond energy for the oxygen molecule.

Bond	Bond Energy (kJ/mol)
C-C	347
C=O	715
C-H	414
O-H	464
O=O	?
C-O	360

2.

(a) When liquid water is introduced into an evacuated vessel at 25^0C, some of the water vaporizes. Predict how the enthalpy, entropy, free energy, and temperature change in the system during this process. Explain the basis for each of your predictions.

(b) When a large amount of ammonium chloride is added to water at 25^0C, some of it dissolves and the temperature of the system decreases. Predict how the enthalpy, entropy, and free energy change in the system during this process. Explain the basis for each of your predictions.

(c) If the temperature of the aqueous ammonium chloride system in part (b) were to be increased to 30^0C, predict how the solubility of the ammonium chloride would be affected. Explain the basis for each of your predictions.

3.

$Br_2(l) + 2\ Fe^{2+}(aq) \rightarrow 2\ Br^-(aq) + 2\ Fe^{3+}(aq)$

For the reaction above, the following data are available:

$2\ Br^-(aq) \rightarrow Br_2(l) + 2e-$ $\quad E^o = -1.07$ volts

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e-$ $\quad E^o = -0.77$ volts

	S^o, J/mole ^oC		
$Br_2(l)$	245.2	$Fe^{2+}(aq)$	–113.4
$Br^-(aq)$	82.0	$Fe^{3+}(aq)$	–293.3

(a) Determine ΔS^o

(b) Determine ΔG^o

(c) Determine ΔH^o

(d) Find K

(e) Does temperature have any affect on the spontaneity of this reaction. Explain.

(f) What would happen to the voltage of the cell if more bromine were added to the cell? Explain.

(g) What would happen to the voltage of the cell if water were added to the cell? Explain.